



**AFRL-RH-BR-TR-2009-0060**

**JOINT SERVICE AIRCREW MASK (JSAM)  
EXTENDED WEAR COMFORT EVALUATION**

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## PREFACE

The contract technical monitor for this work was Mr. Wayne Isdahl, Air Force Research Laboratory, 711 Human Performance Wing, Biosciences and Performance Division (711 HPW/RHPF). The work was performed under work unit number 7757P809; Advanced Concepts in Aircrew Performance and Protection. The research and testing conducted under this work unit was sponsored, funded, and approved by AFRL, 77<sup>th</sup> Aeronautical Systems Group (AESG), and the Joint Strike Fighter (JSF) Joint Program Office.

The operationally relevant objectives, the coordinated involvement of diverse scientific and engineering disciplines, and the rigorous and sustained data collection requirements demanded of this project were successfully accomplished because of an exceptionally qualified and dedicated technical support team. Maj Michael Rutter<sup>3</sup> and Capt Christopher Vojta<sup>3</sup> provided medical coverage for centrifuge and chamber testing sessions. Centrifuge operations were provided by Mr Mac Baker<sup>1</sup>, SSgt Janeth Cubeddu<sup>2</sup>, SSgt Shawn Rose<sup>2</sup>, SSgt Andre Scott<sup>3</sup>, SrA Alexander Hoang<sup>2</sup>, and A1C Christina Gonzales<sup>2</sup>. Maj Thomas Walker<sup>3</sup> served as our Aerospace Physiological Officer for chamber testing sessions. Chamber operations were provided by MSgt Kevin Johnson<sup>3</sup>, MSgt Darci Rose<sup>3</sup>, TSgt Michael Norris<sup>3</sup>, TSgt Kedrick Palmer<sup>3</sup>, and SSgt Andre Scott<sup>3</sup>. Engineering guidance and operations were provided by Mr Nathan Dillon<sup>4</sup> and Mr Tommy Miller<sup>5</sup>. Lt Col Brian Stanley<sup>6</sup> provided valuable operational insight for the testing procedures and debriefings. Most critical, Mr Durrell Bess<sup>1</sup> provided Life Support Equipment training, fitting, and maintenance.

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## **JOINT SERVICE AIRCREW MASK (JSAM) EXTENDED WEAR COMFORT EVALUATION**

### **EXECUTIVE SUMMARY**

At the request of the 77<sup>th</sup> Aeronautical Systems Group, testing was conducted to assess the comfort of the Joint Service Aircrew Mask (JSAM) when worn by aircrew for extended durations under controlled environmental conditions representing high-performance and heavy aircraft operations. JSAM ensembles configured for USAF, Navy, and Army derivations were evaluated. The six test participants were volunteers recruited from the 711<sup>th</sup> Human Performance Wing acceleration and altitude test subject panels. The subjects were male, ranged in age from 28-39 years, physically fit, and considered participation in the test to be a personal challenge. The 12-hour (0700-1900) high-performance aircraft test scenario centered on evaluating the JSAM for use in high-G environments. The simulated operational environments were generated by using the human centrifuge, a flight simulator, and a thermal chamber. The 16-hour (0700-2300) large aircraft test scenario centered on evaluating JSAM for use in long duration airborne operations. The simulated operational environments were generated using a thermal and hypobaric altitude chamber. Approximately every two hours during each test scenario the participants completed two paper-and-pencil surveys. The Comfort Questionnaire identified the subjective degree and anatomical site of any experienced discomfort. The Profile of Mood States provided subjective evaluations of personal emotional status – ‘affect’ or how the subject felt. Comments from the participants and observations from the test team members were also recorded. The JSAM ensemble was successfully worn by all six of the test subjects through the 12- and 16-hour testing periods. Moderate discomfort was reported in a very few instances during the test periods; severe or extreme discomforts were never reported any time during the test periods. The subjects did not experience any affective or emotional distress during the 12- or 16-hour test periods. The subjects and the test team strongly concurred that precise initial fitting of the JSAM by well-trained life support technicians and practiced donning by experienced aircrew are critical for comfortable extended wear.

## **JOINT SERVICE AIRCREW MASK (JSAM) EXTENDED WEAR COMFORT EVALUATION**

### **OBJECTIVE**

This evaluation was requested and the test plan approved by the 77<sup>th</sup> Aeronautical Systems Group (AESG), Brooks City-Base, as meeting the requirements for assessment of comfort during extended wear of the Joint Service Aircrew Mask (JSAM) ensemble as stated in Paragraph 4.3.10.3 of the *System Specification for the Fixed Wing & Optimized Top Owl Joint Service Aircrew Mask (JSAM)* (15 May 2008). Those requirements were:

*“(a) Controlled environment testing for fighter type aircraft shall be based on two 4-hour missions plus ground wear time of four hours for a total wear time of 12 hours. Helmets shall be worn throughout the two 4-hour missions. Night Vision Goggles (NVGs) shall be worn with the helmets for two of the four hours comprising each of the simulated airborne missions.”*

*“(b) Controlled environment testing for bomber and transport type aircraft shall be based on one 12-hour mission with three hours of pre-flight and one hour of post-flight for a total wear time of 16 hours. Helmets shall be worn for at least four hours during the ‘airborne’ portion of the mission. NVGs shall be worn with the helmets for two of the four hours during which the helmets are worn during the simulated mission.”*

### **BACKGROUND**

The Type II Fixed Wing Joint Service Aircrew Mask (JSAM) is a chemical/biological (CB) protective respirator system that provides “above the neck” head-eye-respiratory and percutaneous protection against CB warfare agents, radiological particles, and continuous protection against CB agent permeation for both ground and in-flight operations. When integrated with aircraft-mounted and crew-mounted breathing equipment, the system provides combined hypoxia, CB, and anti-G protection. JSAM provides CB protection for all fixed wing primary aircrew and may be worn by secondary aircrew (e.g., aeromedical evacuation crewmembers). The JSAM system provides the capability for all fixed wing aircrew to fly throughout their full operating envelope and perform their mission in an actual or perceived CB warfare environment. The JSAM includes an above-the-neck sealed hood assembly and a torso-mounted equipment assembly. The above-the-neck sealed hood provides a lens with a field-of-view necessary to perform crew duties, incorporates the MBU-20/P oxygen mask for pressure breathing under G (PBG) aircraft and the MBU-23/P for non-pressure breathing under G (non-PBG) aircraft. It also provides lens anti-fog demist air and circulated air for comfort. The torso-mounted equipment is mounted on the survival vest and includes a battery driven blower/filter assembly for ambient assisted filtered breathing and demist air (primarily used in ground mode), a low profile aircrew filter pack (LPAFP) used to filter aircraft-provided breathing gas, the H-Manifold used to control the airflow for both blower and aircraft air, and the conversational

communication unit (CCU) for ground operations. The combination of the above-the-neck and torso mounted equipment comprises a JSAM “system” or “ensemble.”

## TEST PLAN

**JSAM Personal Equipment Ensembles.** The USAF, the US Navy, and the US Army are each developing slightly different versions of the JSAM ensemble based on some service-unique pieces of life support equipment already in their respective inventories. One derivation of each of their respective versions was tested in this evaluation based on the following lists of personal equipment.

The USAF personal equipment and apparel comprising the USAF version of the JSAM ensemble consisted of:

- Cotton underwear
- CWU-66/P coverall
- Cotton glove insert
- 7 ml butyl glove
- Nomex flyer’s glove
- CSU-13B/P anti-G suit (USAF and Navy fighter/attack only)
- CSU-17/P counter-pressure vest (USAF fighter/attack only)
- JSAM Fixed Wing torso-mounted components
- AIRSAVE vest
- CRU-93/A oxygen regulator (centrifuge mounted component)
- PCU-15/P torso harness
- LPU-36/P life preserver (USAF and Navy fighter/attack only)
- LPU-10/P life preserver (USAF, Navy, and USA bomber/tanker/transport only)
- CRU-94/P oxygen connector
- Joint Services Aircrew Mask/hood (JSAM) – PBG variant or non-PBG variant
- HGU-55/P helmet with NVG mount
- JSAM corrective eye spectacle frame (as prescribed for participant)
- Night Vision Goggles AN/AVS-9 4949G
- Flight boots

The US Navy personal equipment and apparel comprising the Navy version of the JSAM ensemble was the same as the USAF except for:

- Joint Protective Aircrew Ensemble (JPACE) coverall  
(replaced USAF CWU-66/P coverall)
- HGU-68/P helmet with NVG mount  
(replaced HGU-55/P helmet)
- CRU-60/P oxygen connector  
(replaced CRU-94/P oxygen connector)

The US Army personal equipment and apparel comprising the Army version of the JSAM ensemble is the same as the USAF except for:

- Joint Protective Aircrew Chemical Ensemble (JPACE) coverall  
(replaced USAF CWU-66/P)
- HGU-56/P helmet with NVG mount  
(replaced HGU-55/P helmet)
- Air Warrior vest
- Air Warrior micro-climate cooling garment
- Air Warrior soft body armor with ballistic plates
- Green/Black vinyl overshoes

**Subjects.** Qualified volunteers were active duty military personnel holding a current AF FORM 1042 (*Medical Recommendation for Flying or Special Operational Duty*). Three subjects were recruited from the current 711 HPW/RHPF acceleration test subject panel to participate in the “fighter/attack (F/A)” evaluation of the JSAM. Another three subjects were recruited from the current 711 HPW/RHPF altitude test subject panel to participate in the bomber/tanker/transport (B/T/T)” evaluation of the JSAM. Participants ranged in age from 28-39 years of age. All six participants were males, although qualified female panel members were eligible to volunteer. The fact that they were qualified volunteer members of the test subject panels attests to the subjects’ above-average-to-excellent physical conditioning, and their shared trait of being self-motivated to excel in challenging situations - in this case, to successfully complete all phases of their JSAM test scenarios. Given their high-motivation to succeed, the subjects were periodically reminded during testing of the critical importance of reporting each discomfort and design problem in order to develop and field the most comfortable system possible.

**Familiarization and Equipment Fitting.** One or two days prior to conducting the test scenarios, each volunteer reported to the Cockpit and Equipment Integration Laboratory (CEIL) to be “fitted” with their assigned ensemble and become familiar with the two surveys they would be completing periodically during testing. Mask sealing tests were conducted using a Gentex Life Support Integrated Test Set (Model 1/A) to assure an acceptable fit. The mask-sealing test employed mask tube pressures of 30 mm Hg and an acceptable leak rate no greater than 5L/min. The participants were instructed on the use of the various mask features, including donning/doffing and drinking access. The participants were also instructed on the symptoms of early heat stress, including feeling faint, muscle cramps, profuse sweating, and nausea.

Within the three-member F/A group, two were fitted for the USAF JSAM ensemble incorporating the positive pressure-breathing (PBG) variant of JSAM. The third member of the F/A group was fitted for the US Navy JSAM ensemble incorporating a non-PBG variant. The USAF PBG variant is based on the CRU-93/A panel mounted oxygen regulator and the HGU-55/P helmet currently employed in the F-15 and F-16. The US Navy non-PBG system uses the chest-mounted CRU-103/P regulator and the HGU-68/P helmet currently employed in the F-18. The US Army does not have a requirement for the JSAM system in a fighter/attack, high-G environment.

Each of the three participants assigned to the B/T/T group wore one of the variants representing each of the three services. The personal anti-G components of the ensemble worn in the USAF and Navy F/A variants are not required in the B/T/T setting and, thus, were not

included in the B/T/T ensembles. Otherwise the USAF and Navy B/T/T ensembles were the same as their respective F/A ensembles. The components comprising the Army ensemble were as described above.

**Simulated Aircrew Duty Day Scenarios.** The 12-hour F/A test scenario was centered on evaluating JSAM variants configured for use in high-G environments. The simulated operational environments selected for the F/A test scenario were generated using the Gyroflight Sustained Operations Simulator<sup>1</sup> (GSOS), the Altitude/Environmental Chamber-E, and the human-rated centrifuge. The B/T/T test scenario was centered on evaluating JSAM variants configured for use in long range, extended duration, airborne operations. The B/T/T simulated operational environments were generated using the Altitude/Environmental Chamber-E. The B/T/T participants wearing the USAF and Navy versions wore their respective JSAM ensembles for 16 hours; the B/T/T participant wearing the US Army version wore the JSAM ensemble for 12 hours.<sup>2</sup> During the test scenarios water, Gatorade®, and Ensure® were available ad lib to be consumed using the mask's drinking tube connected to a canteen. Participants were allowed to remove equipment and apparel as necessary to use the bathroom. Each participant was under constant observation by members of the evaluation team throughout all phases of training and testing.

**Data Collection.** Approximately every two hours during each test scenario the participants completed the two paper-and-pencil surveys. The Comfort Questionnaire (CQ; Figure 1) identified the anatomical site and the subjective degree of any experienced discomfort or pain. The CQ was a modified version of a survey developed for and applied in the previous extended wear test of the Aircrew Eye/Respiratory Protection (AERP) mask.<sup>3</sup> Written comments supplementing the ratings were encouraged. Subjective evaluations of mood or affect were acquired using the Profile of Mood States (POMS). The POMS consists of a listing of 65 adjectives ("feelings") that are each rated by the participant on a five-point scale. A standardized score is generated for each of six categories: anger, confusion, depression, fatigue, tension, and vigor. The instructions to the participant on completing both the CQ and the POMS were to respond as to "...how you are feeling *RIGHT NOW*" to accommodate repeated application during the test scenarios.

Evaluators from the 77<sup>th</sup> AESG also collected data using the Fit Factor Test to quantitatively measure the degree to which a simulated agent could penetrate the JSAM hood just after donning and just before doffing the ensembles. These findings will be reported independently.

## **F/A 12-HOUR TEST SCENARIO (Table 1)**

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<sup>1</sup> The GSOS is a motion-based (four degrees of freedom), single-seat flight simulator. It is specifically designed and engineered to conduct spatial disorientation research and training in a motion-based flight simulation environment.

<sup>2</sup> The US Army does not have a formal doctrine addressing a fixed wing mission day. US Army TRADOC (Mr. John Popovich) directed evaluating a total wear time of 12 hours; eight hours while "flying" and four hours while "on the ground."

<sup>3</sup> Nunneley, S.A., and Russell, R.L. Aircrew Eye/Respiratory Protection (AERP): 16-Hour Extended Wear Evaluation of Chemical Protective Equipment, AL-TP-1993-0014, 1994.

**0600-0700.** On their assigned testing day, the F/A subjects reported to the CEIL at 0600 to don the JSAM ensemble and otherwise prepare for the 0700 start of their test scenarios. Standard sternal and biaxillary electrocardiogram (ECG) electrodes were attached to each of the subjects to allow periodic monitoring of heart rate during the test scenario. The CEIL technician assured proper fitting and functioning of their previously assigned and fitted personal life support equipment. As during the prior fitting sessions, mask-sealing tests were conducted using a Gentex Life Support Integrated Test Set (Model 1/A) to assure an acceptable fit. Once again, mask tube pressures of 30 mm Hg and an acceptable leak rate no greater than 5L/min were employed. Once properly fitted each participant participated in the Fit Factor Test and then completed both surveys. They then removed their helmets and NVGs until their scheduled re-donning later in the test scenario at the start of the four-hour simulated sortie at the GSOS facility.

**0700-0800.** At 0700 the F/A participants were escorted from the CEIL to the GSOS facility (both located in building 170) where they received orientation and training from 0700-0800 on the basics of flying the GSOS. The intent of including the GSOS was to provide the participants with an interesting and relevant task during at least a portion of their simulated 12-hour duty day. During this session they received basic flight instruction and an introduction to the basic flight controls in the GSOS. There were no expectations for their “piloting” ability and no GSOS performance data were collected. Neither helmets nor NVGs were worn during this session.

**Table 1. Testing Schedule for Fighter/Attack (F/A) Scenario**

Event Simulated	Start Time	End Time	Facility/Activity	Configuration	
				Helmet	NVGs
Show	0600	0700	CEIL: Don; Baseline data	X	X
Preflight Brief	0700	0800	GSOS: Orientation & Training	-	-
Preflight Check	0800	0900	Chamber-E: 110°F; Treadmill	-	-
4-Hr Mission	0900	1100	GSOS: Fly simulator	X	X
	1100	1300	Centrifuge: +Gz runs	X	-
Break	1300	1400	CEIL:	-	-
Preflight Check	1400	1500	Chamber-E: 110°F; Treadmill	-	-
4-Hr Mission	1500	1700	GSOS: Fly simulator	X	X

	1700	1900	Centrifuge: +Gz runs	X	-
Debrief	1900	2000	CEIL: Doff; Final data	-	-

**0800-0900.** At 0800 the F/A participants were escorted on foot to the chamber facility in building 160 where they were sequentially exposed in Chamber-E to 110 °F (43 °C) at 20% relative humidity at ground level for 20 minutes. During the first and last five minutes of the 20-minute session the subjects were seated. During the mid portion of each of their 20-minute exposures they performed 10 minutes of light exercise by walking on a mechanized treadmill with 0° slope at 2.5 mph. Neither helmet nor NVGs were worn during this session. Each participant completed both surveys immediately at the end of the 20-minute thermal exposure. When not in the chamber during this session the participants were monitored while seated in the chamber complex facility, which was maintained at a room temperature of approximately 73 °F.

**0900-1100.** At 0900 the F/A participants were escorted back to building 170 to begin the first of two 4-hour simulated missions. The first two hours of the simulated mission occurred at the GSOS; the second two hours immediately followed at the centrifuge. On arriving at the GSOS all three participants donned their helmet and NVGs and from 0900-1100 each, in turn, piloted the GSOS for 30-40 minutes. Each was allowed to fly basic flight maneuvers. A console operator was available at all times to instruct the participants or to terminate the flight simulator profile if necessary. Test evaluators were also always in the immediate area. Each participant completed the surveys on completion of his piloting session. When not piloting during the GSOS session the participants continued wearing their helmets and NVGs and remained in the GSOS area where, under constant observation, they were able to relax in an office environment, reading, watching movies, or cat napping.

**1100-1300.** On completion of the GSOS session at about 1100, the three F/A participants immediately walked to the centrifuge facility to complete the last two hours (1100-1300) of the simulated mission. At this point they removed their NVGs but continued wearing their helmets for two more hours, including during their centrifuge runs. During the centrifuge runs the participants were seated in an F-16 ejection seat mounted in the centrifuge gondola. The seat had restraint belts to provide protection during +Gz-sustained acceleration.

The acceleration profiles for the two F/A participants wearing the USAF variant of the JSAM consisted of centrifuge runs with rapid onset rates of 6 +Gz/s. The first three positive-pressure-breathing-under-G (PBG) runs consisted of 5, 7, and 9 +Gz exposures for 15s each. Two-minute rest periods occurred prior to each of these runs. After a five-minute rest period, the fourth PBG run simulated aerial combat maneuvers (SACM) of alternating 10s plateaus at +5 Gz and +9 Gz until the subject chose to terminate the ride or he completed four +9 Gz plateaus. When pressure breathing was required, pressurized air was delivered by means of the CRU-93/A regulator according to the standard PBG schedule for COMBAT EDGE - that is, the PBG started at +4 Gz and increased in pressure by 12 mm Hg/G to a maximum of 60 mm Hg at +9 Gz. COMBAT EDGE is the positive pressure breathing system that helps provide protection against high G in the F-15, F-16, and F-22. G-suit inflation during all centrifuge runs followed a standard COMBAT EDGE schedule.

The first three acceleration profiles for the single F/A participant wearing the US Navy variant of JSAM consisted of centrifuge runs of 5, 6, and 7.5 +Gz exposures for 15s each. Two-

minute rest periods occurred prior to each of these runs. A fourth non-PBG run simulated the +Gz-stress of repeated '1 vs. 1' F/A-18 maneuvers. This profile simulated four offensive high +Gz passes and lasted approximately 130s. The first pass had a 6 G/s onset to a 10s +7.5Gz plateau; the +Gz reduced over the next 10s at 0.2 G/s (to +5.5Gz) then returned to +1.4Gz for 10s. The second pass had a 6 G/s onset to a 10s +7.0Gz plateau; the +Gz reduced over the next 10 s at 0.2 G/s (to +5Gz) then returned to +1.4Gz for 10s. The third pass had a 6 G/s onset to a 10 s +6.5Gz plateau; the +Gz reduced over the next 10 s at 0.2 G/s (to +4.5Gz) then returned to +1.4Gz for 10 s. The fourth pass had a 6 G/s onset to a 10 s +6.0Gz plateau; the +Gz reduced over the next 10s at 0.2 G/s (to +4Gz) then returned to +1.4Gz. The 10s 0.2 G/s offset and successive lower +Gz plateaus mimicked the reduced energy available during a sustained maneuver over the four passes.

Forty minutes were allotted for each participant's centrifuge exposure. Each participant completed the two surveys on completion of their centrifuge run. Following standard operating instructions and procedures, each participant's ECG was continuously monitored during the centrifuge runs. When not riding the centrifuge during the session, the participants continued wearing their helmets and remained in the centrifuge facility area where, under constant observation, they were able to relax in an office environment and allowed to read or watch their fellow subjects on closed circuit television during each other's centrifuge runs.

**1300-1400.** The F/A participants were given a rest break in a lounge facility in building 170 during which they did not wear helmets or NVGs. Again, they were under constant observation and communication with test evaluators. Both surveys were completed at the end of the break.

**1400-1900.** Beginning at 1400, the three F/A participants repeated the previously completed schedule starting with being exposed without wearing helmets or NVGs to 110 ° F/20% relative humidity and light exercise in Chamber-E from 1400-1500; then the four-hour simulated mission comprised of the two-hour session (1500-1700) at the GSOS wearing helmet and NVGs, followed by the two-hour session (1700-1900) at the centrifuge continuing to wear the helmets but not the NVGs. The two surveys were completed as previously scheduled following completion of each activity.

**1900-2000.** The 12-hour F/A test scenario was completed at 1900. On completion of the centrifuge trials the F/A participants were escorted to the CEIL where they participated in the Fit Factor Test and were then assisted in removing their JSAM ensembles. The surveys were administered a final time and any comments noted in the test log.

## **B/T/T 16-HOUR TEST SCENARIO (Table 2)**

**0600-0700.** On their assigned testing day, the three B/T/T subjects reported to the CEIL at 0600 to don and otherwise prepare for the 0700 start of their test scenario. Standard electrocardiogram (ECG) electrodes were attached to each of the primary subjects to allow periodic monitoring of heart rate during the test scenario. The CEIL technician assured proper fitting and functioning of their previously assigned and fitted personal life support equipment. As during the prior fitting sessions, mask-sealing tests were conducted using a Gentex Life



Support Integrated Test Set (Model 1/A) to assure an acceptable fit. Once again, mask tube pressures of 30 mm Hg and an acceptable leak rate no greater than 5L/min were employed. Once properly fitted each participant participated in the Fit Factor Test and then completed both surveys. They then removed their helmets and NVGs until their scheduled re-donning later in the test scenario during the extended simulated airborne mission in Chamber-E.

**0700-0800.** On completion of donning their JSAM ensembles and the collection of preliminary data, the three B/T/T participants were allowed to occupy themselves in a lounge/conference room environment from 0700-0800, reading, using a lap top computer, etc. They did not wear helmets or NVGs during this period.

**0800-0900.** At 0800 the B/T/T participants were escorted on foot to the chamber facility in building 160 where they were sequentially exposed in Chamber-E to 110 °F (43 °C) and 20% relative humidity at ground level for 20 minutes. During the mid portion of each of their 20-minute exposures, they performed 10 minutes of light exercise by walking on a mechanized treadmill with 0° slope at 2.5 mph. When not on the treadmill during their 20-minute exposure, the subjects were seated within the chamber. Neither helmet nor NVGs were worn during this session. Each participant completed both surveys on completion of their 20-minute thermal exposure. When not in the chamber during this session, the participants were monitored while seated in the chamber complex facility.

**Table 2. Testing Schedule for Bomber/Tanker/Transport (B/T/T) Scenario**

Event Simulated	Start Time	End Time	Facility/Activity	Configuration	
				Helmet	NVGs
Show	0600	0700	CEIL: Don; Baseline data	X	X
Preflight Brief	0700	0800	CEIL facility	-	-
Preflight Check	0800	0900	Chamber-E: 110°F; Treadmill	-	-
Preflight Brief	0900	1000	Chamber facility	-	-
12-Hr Mission	1000	1200	Chamber-E: 8,000 ft altitude <sup>1</sup>	-	-
	1200	1400	“	X	X
	1400	1600	“	-	-
	1600	1800	“	X*	-
	1800	2000	“	-	-
	2000	2200	“	-	-
Postflight	2200	2300	CEIL facility	-	-
Debrief	2300	0000	CEIL: Doff; Final data	-	-

<sup>1</sup> The subjects breathed ambient air through the JSAM blower set in ground mode from 1000-1200, 1400-1600, and 1800-2200; they breathed through aircrew regulators from 1200-1400 and 1600-1800.

\*The subject wearing the US Army ensemble removed his helmet and exited the chamber at 1800, having completed his simulated 8-hour "mission." The subject was escorted to the CEIL where he was monitored from 1800-1900. From 1900-2000 the subject doffed the ensemble, debriefed, and released.

**0900-1000.** The B/T/T participants remained at the chamber complex facility and were allowed to occupy themselves in an office/conference room environment during this period, reading, etc. They did not wear helmets or NVGs during this period.

**1000-2200.** At 1000 the three B/T/T participants were escorted back into Chamber-E where they were exposed to a simulated long duration airborne mission. As a group, the three participants were taken from ground level to 8,000-foot simulated cabin altitude and remained there for their assigned duration. The chamber was stabilized at a temperature of  $70^{\circ}\pm 2^{\circ}\text{F}$  for the duration of the simulated airborne session. The simulated mission was 12 hours in duration for the participants wearing the USAF and US Navy JSAM configurations, but was limited to the first 8 hours in duration for the participant wearing the US Army version. The rate of ascent and descent was 5,000 ft/min. From 1000-1200 the three participants did not wear helmets or NVGs and breathing air was provided by the JSAM blower set in ground mode; 1200-1400 they wore both helmets and NVGs and were connected to aircrew regulators; 1400-1600 they did not wear helmets or NVGs and breathed ambient air; 1600-1800 they wore helmets but not NVGs and were connected to aircrew regulators.

At 1800 the participants removed their helmets. The participant wearing the US Army version departed the chamber via the chamber-lock accompanied by a physiological technician. The other two participants continued at altitude from 1800-2200 while not wearing helmets or NVGs and breathing ambient air. The US Army participant was escorted to the CEIL where he relaxed from 1800-1900. From 1900-2000 he completed the Fit Factor Test before being assisted in doffing the ensemble, final data collection, debriefed, and allowed to depart. Chamber-E was returned to ground level at 2200 and the two participants wearing the USAF and Navy versions exited the chamber and returned to the CEIL.

While at altitude, the three B/T/T participants completed the two surveys at 1000 just after reaching 8,000 feet; at 1200 just before donning helmets and NVGs; at 1400 just after doffing helmets and NVGs; at 1600 just before donning helmets; at 1800 just after doffing helmets; and, for the two subjects wearing the USAF and Navy versions, at 2000 and 2200 just after exiting the chamber. The participants provided their own materials to occupy the considerable sedentary time they had during the simulated mission.

**2200-2300.** The two B/T/T participants wearing the USAF and Navy versions were allowed to occupy themselves in an office/conference room environment during this period, reading, napping, watching movies, etc. They did not wear helmets or NVGs during this period.

**2300-0000.** The B/T/T test scenario was completed. On completion of their test scenario the remaining two B/T/T participants completed the Fit Factor Test and were then assisted in removing the JSAM and associated life support equipment. The surveys were administered a final time and any comments noted in the test log.

## **SURVEY FINDINGS FOR F/A JSAM EXTENDED WEAR TESTING**

**Overview.** All three F/A subjects completed all phases of their 12-hour test scenario without incident or serious complaint. The three subjects were representative of fighter/attack aircrew: their ages were 28, 32, and 39 years; all were in excellent physical condition; and all were exceptional centrifuge riders. Subject #2 was a moderate cigarette smoker.

**Comfort Questionnaire (CQ).** The CQ was completed nine times as scheduled throughout the 12-hour F/A test period. It is notable that ratings of SEVERE or EXTREME discomfort were not reported at any time during the test period. An overview is presented in Table 3 for the NONE, SLIGHT and MODERATE discomfort ratings reported across the nine administrations to the three subjects. The most frequently reported CQ rating, by far, was NONE, indicating no discomfort. The most intense discomfort level experienced at any time during the 12-hour test period was that of MODERATE, and then in only four instances. Discomfort ratings of SLIGHT occurred occasionally, but much less frequently than ratings of NONE. Most of the SLIGHT and two of the MODERATE discomfort ratings referenced the neck, torso, and face areas. Most of the ratings of SLIGHT came from Subject #2 and, though he reported many of these ratings early on and throughout the test period, they never progressed from SLIGHT to MODERATE. Comments made by the subjects and members of the test team during each of the CQ administrations are presented in Table 4. Most of the CQ ratings of SLIGHT were not accompanied by comments from the subjects as they considered the level of discomfort being reported to be manageable and not of significance.

- Subject #3, wearing the Navy ensemble, reported MODERATE discomfort at the back of his head soon after donning his ensemble. He also noted the NVGs caused the brow pad to push down on his brow forcing him to have to actively raise his eye brows in order to see. The helmet and mask were immediately removed from the subject and refitted, providing him some relief. However, he continued throughout the test to report pressure from the helmet on the back and sides of his head, and the brow pad slipping during centrifuge runs.

- The other three ratings of MODERATE discomfort were each reported in association with the second centrifuge exposure; two from Subject #2 and one from Subject #3. Subject #2 reported that the two ratings of MODERATE regarding his lower arm and hand were the result of him not being able to properly/comfortably position his arm prior to G onset due to the bulk of the ensemble and, therefore, the G forces pushed his arm and thumb backwards to an uncomfortable position.

- Subject #3 related his report of MODERATE discomfort during his second centrifuge run to the bulk and placement of the JSAM equipment on his lower torso. He reported that it was difficult to do anti-G contractions during the 7G runs, perhaps due to the location of his seat belt over the G-suit bladder. He did not report similar discomfort during his first centrifuge run.

- Interpretation of Subject #2's relatively profuse reports of SLIGHT discomfort ratings is readily tempered by the fact that the ratings were consistently directed at the same areas (neck, torso, and hands) and, more important, they never increased in severity over the 12-hour test session. His ratings likely reflect his awareness and acceptance of what he termed "*adjusting to the weight*" of the "*heavy gear*."

**Profile Of Mood States (POMS).** At each survey administration the POMS was administered immediately after completing the CQ. Their POMS scores indicated absolutely no feelings of *tension*, *depression*, *anger*, or *confusion* throughout the 12-hour test. Over time, both a mild decline in *vigor* (feelings of friendliness and positive affect) and a slight increase in

*fatigue* likely reflected the impact of wearing of the JSAM ensembles for an extended period, combined with a long, tedious day.

**Table 3. F/A Ratings\* on Comfort Questionnaire (CQ)**

[illegible]

BACK OF BODY																																					
	neck			arms									hands			torso									legs						feet						
CQ item #	1			2			3				4				5				6			7				8				9			10				11
Subject #	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Post-don JSAM		•																																			
Post-1 <sup>st</sup> thermal		•																	•																		
Post-GSOS training		•																	•			•	•														
Post-1 <sup>st</sup> centrifuge		•																	•			•															
Post-rest break		•																	•																		
Post-2 <sup>nd</sup> thermal		•																	•																		
Post-GSOS flying		•	•																•			•	•														
Post-2 <sup>nd</sup> centrifuge		•	•												×				•			•															
Post-doff JSAM																																					

[illegible]

- \*
  - ☐ no discomfort
  - ☒ slight discomfort
  - ☐ moderate discomfort

**Table 4. F/A Subject and Test Team Comments  
Provided on Comfort Questionnaire**

Subject #	CQ Item #	CQ Rating	Comments*
<b>Post-don JSAM (0745)</b>			
1	18-mouth & nose	slight	Felt pressure on the bridge of nose
3	12-top of head	slight	NVGs cause headband to push down on brow forcing me to raise brows to see.
3	15-back of head	moderate	Pressure from helmet felt on lower left and right back of head. <i>(USN helmet has a larger edge roll around helmet. Is rear cutout of USN helmet smaller than that of a USAF helmet?)</i>
<b>Post-1<sup>st</sup> thermal exposure (0845)</b>			
3	general		Reported a 'slight' sweat <i>(subject is into physical fitness)</i>
<b>Post-GSOS training (1100)</b>			
2	general		<i>(Subject reported blower weakening; batteries were replaced and all better. Subject did not feel his reporting feeling a little fatigued on the POMS was due to breathing – just general malaise and inactivity.)</i>
3	13 & 14-sides of head	slight	Pressure on both ears from the helmet.
<b>Post 1<sup>st</sup> centrifuge ride (1230)</b>			
1	2-front of shoulders	slight	Slight shoulder pain in right arm.
1	9-front upper legs	slight	Thigh pressure on outer part of thigh with G-suit inflated; Both legs, same spot.
1	10-front lower legs	slight	Ankle pressure with anti-G suit inflated.
1	18-mouth & nose	slight	Mask pressure on bridge of nose.
2	6,7,8-front of torso	slight	Adjusting to weight and G-suit pressure.
2	17-left front of head	slight	Mask adjustment made to push up against face at 9G.
3	general		<i>(Brow pad kept slipping down during centrifuge run.)</i>
<b>Post-rest break (1400)</b>			
			<i>No comments offered.</i>
<b>Post 2<sup>nd</sup> thermal exposure (1445)</b>			
			<i>No comments offered.</i>

\*Comments from test team members are presented in italics.

(table continued on next page)

**Table 4. (continued from previous page) F/A Subject and Test Team Comments  
Provided on Comfort Questionnaire**

Subject #	CQ Item #	CQ Rating	Comments*
<b>Post-GSOS flying (1630)</b>			
2	general		<i>(Subject said that JSAM hood material rubbing against earpieces of helmet was becoming a slight annoyance.)</i>
3	general		<i>(Brow pad fell down about to eye level.)</i>
3	15-back of head	slight	Pressure on right rear of helmet.
<b>Post 2<sup>nd</sup> centrifuge ride (1800)</b>			
1	1-neck	slight	Stiffness in the neck prior to run. Probably from excessive equipment.
2	4-front of lower arm	moderate	Arm positioning was wrong; G forces moved arm past body.
2	5-back of hand	moderate	Thumb twisted backwards due to G forces.
2	6,7,8-front of body	slight	Gear heavy.
3	8-front of lower torso	moderate	During 7G runs, air (JSAM equipment) pouch and seat harness added pressure to abs; made it moderately difficult to do contraction. May have been (due to) location of seat belt over G-suit bladder. <i>(Subject said he really cinched seat belt really tight over anti-G suit stomach bladder.)</i>
<b>Post-doff JSAM (1915)</b>			
			<i>No comments offered.</i>

## **SURVEY FINDINGS FOR B/T/T JSAM EXTENDED WEAR TESTING**

**Overview.** All three B/T/T subjects completed all phases of their test scenarios without incident or serious complaint. The three subjects were 39, 31, and 39 years of age and were in above-average to excellent physical condition. Subject #6 wore JSAM eyeglass frames containing his optical prescription.

**Comfort Questionnaire (CQ).** The CQ was completed ten times as scheduled by the USAF and Navy subjects (#4 and #5, respectively) and eight times by the US Army subject (#6). As with the F/A subjects, ratings of SEVERE or EXTREME discomfort were not reported at any time during the test period. An overview is presented in Table 5 for the NONE, SLIGHT, and MODERATE discomfort ratings reported across the survey administrations to the three subjects. By far the most frequently reported CQ discomfort rating was NONE. Ratings of MODERATE discomfort were reported in only seven instances, five by subject #5 and two by subject #6. Twelve of 25 discomfort ratings of SLIGHT referenced the head area. Comments made by the subjects and members of the test team during each of the CQ administrations are presented in Table 6. Not all the ratings of SLIGHT discomfort were accompanied by comments.

- Subject #5's earliest report of MODERATE discomfort occurred after being at altitude for four hours (1400) and related to his lower left back but seemed to pass as it was never mentioned again. A rating of MODERATE discomfort from a hot spot on the tip of his right ear was reported at eight hours into the mission (1800), and was mentioned as still a bit sore at the post-doff debrief. Two ratings of MODERATE discomfort from the butt were reported late into the simulated 12-hour mission at 2000 and 2200, obviously caused by having been sitting for most of the past several hours. At 2000 subject #5 reported a SLIGHT discomfort from the palms of his hands becoming wet, and elevated the discomfort to MODERATE at the end of the simulated mission at 2200.

- Subject #6's two CQ reports of MODERATE discomfort occurred at six and eight hours into his eight-hour mission, both due to the mask's rubber dam irritating his neck.

**Profile Of Mood States (POMS).** At each survey administration the POMS was administered immediately after completing the CQ. The POMS scores indicated the three subjects did not experience even low levels of affective or emotional distress during the 12- and 16-hour test periods. Over time, very slight changes in POMS *vigor* and *fatigue* reflected the stamina the subjects brought to bear on a long test period even more tedious than that experienced by the F/A subjects.



**Table 5. B/T/T Ratings\* on Comfort Questionnaire (CQ)**

FRONT OF BODY																																	
	neck			arms						hands			torso						legs						feet								
CQ item #	1			2			3			4			5			6			7			8			9			10			11		
Subject #	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6			
Post-don JSAM																																	
Post-thermal											•																	•					
Altitude 0hr																																	
Altitude +2hr																																	
Altitude +4hr		•	•																														
Altitude +6hr			×																														
Altitude +8hr			×		•																												
Altitude +10hr					•						•			•																			
Altitude +12hr												×																					
Post-doff JSAM												•																					

BACK OF BODY																																	
	neck			arms						hands			torso						legs						feet								
CQ item #	1			2			3			4			5			6			7			8			9			10			11		
Subject #	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6			
Post-don JSAM																		•															
Post-thermal																																	
Altitude 0hr																																	
Altitude +2hr																																	
Altitude +4hr			•																×			•											
Altitude +6hr																																	
Altitude +8hr			•																														
Altitude +10hr																										×							
Altitude +12hr																										×							
Post-doff JSAM																																	

HEAD																					
	top			right side			left side			back			right front			left front			chin/nose		
CQ item #	12			13			14			15			16			17			18		
Subject #	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
Post-don JSAM					•																
Post-thermal																					
Altitude 0hr																					
Altitude +2hr																					
Altitude +4hr	•				×			•						•			•			•	
Altitude +6hr																					
Altitude +8hr					×									•							
Altitude +10hr												•									
Altitude +12hr	•											•								•	
Post-doff JSAM					•																

*	
<input type="checkbox"/>	no discomfort
<input checked="" type="checkbox"/>	slight discomfort
<input checked="" type="checkbox"/>	moderate discomfort

**Table 6. B/T/T Subject and Test Team Comments  
Provided on Comfort Questionnaire\***

Subject #	CQ Item #	CQ Rating	Comments*
<b>Post-don JSAM (0815)</b>			
5	13-right side of head	slight	Right ear tip has small hot spot. Feels like a seam or strap.
6	6-upper back	slight	From weight of the equipment.
<b>Post-thermal (0905)</b>			
5	4-upper front of body	slight	Right forearm; can feel chaffing from suit internal, closure cuff about six inches above waist.
5	10-front of body	slight	Right shin; feel chaffing on front of ankle and right above boot line. Both are at seams. I think the ankle is where internal suit cuff ends and upper is the seam.
<b>Altitude 0hr (1025)</b>			
			<i>No comments provided.</i>
<b>Altitude +2hr (1215)</b>			
			<i>No comments provided.</i>
<b>Altitude +4hr (1410)</b>			
4	12-top of head	slight	Pressure at/on bridge of nose. May be due to weight of NVG pushing down on helmet/mask.
5	1-front of neck	slight	There is an area on the front of the mask that is very stiff and pushes on the throat.
5	1-back of the neck	slight	Some neck discomfort and fatigue.
5	7-mid to lower back	moderate	Can feel a pulling on lower left side.
5	8-lower back, buttocks	slight	Butt tired of sitting.
6	1-front of neck	slight	Seems like head or hoses are backing up a little.
<b>Altitude +6hr (1600)</b>			
6	1-front of neck	moderate	Front of neck is starting to get irritated by rubber sleeve.

*\*Comment from test team members are presented in italics.*

(table continued on next page)

**Table 6. (continued from previous page) B/T/T Subject and Test Team Comments  
Provided on Comfort Questionnaire\***

Subject #	CQ Item #	CQ Rating	Comments*
<b>Altitude +8hr (1810)</b>			
5	1-back of neck	slight	Neck starting to feel fatigue.
5	2-shoulders	slight	Left shoulder has discomfort from vest and LPU. Can get some relief with adjustment.
5	13-right side of head	moderate	Hot spot on tip of ear from elastic.
5	16-right front of head	slight	Below and to right of zygomatic arch, the mask and helmet edge bind and created a hot spot. Near D-ring.
6	1-front of neck	moderate	Same as stated above – rubber sleeve around neck.
<b>Altitude +10hr (2000)</b>			
4	15-back of head	slight	Neck seal seems to roll and pinch along the neck in front. Velcro beginning to rub.
5	2-front of shoulders	slight	Left shoulder still about same.
5	4-front of lower arms	slight	Condyle of ulna and wrist developing a hot spot. Left hand
5	5-hands	slight	Palms are getting irritated from being wet.
5	8-buttocks	moderate	Butt cheeks getting tired.
<b>Altitude +12hr (2200)</b>			
4	15-back of head	slight	Hood pinching at neck.
5	5-hands	moderate	Palms still irritated.
5	8-buttocks	moderate	Butt still complaining.
5	18-mouth and nose	slight	Lips starting to dry and chap.
<b>Post-doff JSAM (1930 for #6; 2330 for #4 &amp; #5)</b>			
4	general		Overall few problems. Chem gear is uncomfortable; as a flyer, the JSAM would not be that difficult to operate.
5	5-hands	slight	Palms sensitive due to being damp.
5	13-right side head	slight	Right side of ear tip still a little sore.
5	general		I liked the blower feature. It made the mask less claustrophobic with the cool breeze. Although it does make it harder to hear without headset. The seam running vertical in front was very stiff and irritating to the throat, Adam's apple. The elastic across the ears was bad, created hot spots on tips. I have worn MOPP-4 for 12 hours, JLIST, and this was better. With the helmet on the ear, hot spots were worse and I got a hot spot along my right jaw where the D-ring and roll meet. Maybe wear one size larger helmet with JSAM.

## CONSOLIDATED FINDINGS

**Overview.** The ratings and inputs discussed above from the two surveys were combined with additional comments made by the participants at the debriefings and the comments noted in logbooks by the test team. This input was collated and consolidated by topics, resulting in the following overall findings.

**JSAM Fitting.** It is critical, especially for extended wear, that the JSAM ensemble initially be fitted with some precision to each individual crewmember. The test participants and the test evaluators all concluded that, even after an initial precise fitting, donning the JSAM ensembles requires a closely coordinated, well rehearsed effort between aircrew and life support personnel. An individual crewmember cannot don the JSAM ensemble by him/herself. It is also important, again especially for long term wear, that each donning take care to avoid potential latent irritants such as twisted straps, a bunched hood, or a rolled up neck dam, and to insure proper operation of JSAM features such as the drinking straw and demist blower.

**Navy Helmet.** Both the F/A and B/T/T participants assigned to wear the Navy JSAM ensemble had difficulty donning the Navy HGU-68/P helmet over the hood and mask. The brow band came loose during donning and, for the F/A participant, the band slipped downward repeatedly during high-G runs on the centrifuge and when donning NVGs, making it difficult to see. A test team member noted that the relatively larger edge roll in the Navy helmet may contribute to this problem. Both 'Navy' participants reported discomfort with the ear cups, with hot spots and pressure on their ears. It may be that some or all of these discomforts occurred because the one Navy helmet available for this test, a size 'large,' may have been too small for the participants. However, based on their anthropometries, both subjects assigned to wear the Navy ensemble should have comfortably worn a size 'large' HGU-68/P helmet. Given the subjects' discomfort with a size 'large' helmet, the CEIL life support technician would have replaced and compared it with a size 'extra-large' helmet had one been available.

**Drinking Straw.** At debrief, all six participants found the ability to intake liquids to be acceptable, but reported a longer straw would improve the ease of use. Some also reported that it was necessary to aggressively suck the tube to get adequate liquid. While being used, the straw actually came off and drawn into the mouth of one participant. It was necessary to doff the mask in order to retrieve and repair the tube.

**Physical Burden.** During debrief, all six of the participants reported their mobility while wearing the ensembles to be acceptable. Subject #6 (B/T/T-Army) stated the burden to "same as other similar ensembles – you notice it but it's not that bad." The overall physical burden was noted by some of the participants but all found it to be acceptable. Subject #6 reported wearing the flak vest to be acceptable. All reported heat stress to not be a problem, including during the 20-minute thermal exposure. Subject #5, wearing the Navy B/T/T ensemble, did report his palms became wet during the last few hours on the test session.

**Vision.** During debrief the participants reported eye comfort to be acceptable, occasionally noticing minor eye discomfort due to the dry air but it seemed to “come and go.” The B/T/T subject assigned to wear the Army ensemble reported the compatibility and comfort of the JSAM while wearing eyeglass frames was very acceptable. Their ability to see was reported as acceptable. No fogging of the visor was reported.

**Acceleration.** As discussed above, three of the four F/A ratings of MODERATE discomfort occurred during exposure to high G by two of the F/A participants. In all three cases, the discomfort reported resulted not directly from wearing the JSAM ensemble, but indirectly due the participants not properly positioning themselves prior to G-onset.

## **SUMMARY**

The JSAM ensemble was successfully worn by test subjects through 12- and 16-hour test periods representing, respectively, high-performance F/A and large B/T/T aircraft extended aircrew duty days. On a survey scale ranging from none-to-extreme, moderate discomfort was reported in a very few instances during the test periods; severe or extreme discomfort were never reported any time during the test periods. Precise initial fitting of the JSAM by well-trained life support technicians and practiced donning by experienced aircrew are critical to comfortable extended wear.

**Figure 1. JSAM Comfort Questionnaire**

Subject ID: \_\_\_\_\_

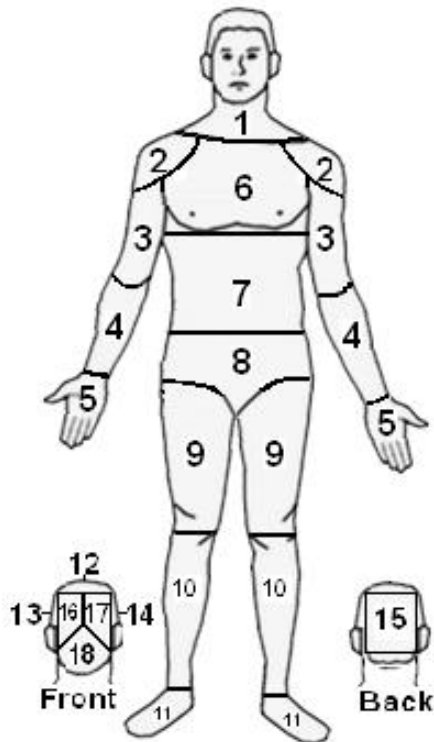
Date/Time (L): \_\_\_\_\_

Location/Event: \_\_\_\_\_

Instructions: Rate the degree if any of soreness, pain, or discomfort that you are currently feeling for body parts 1 – 18. Do so for the front and the back of the body. Note that 16, 17, and 18 apply only to the front of the head, whereas 15 applies only to the back of the head. Check a box for each body part.

**Front of Body**

	1	2	3	4	5	6	7	8	9	10	11
NONE											
SLIGHT											
MODERATE											
SEVERE											
EXTREME											



**Back of Body**

	1	2	3	4	5	6	7	8	9	10	11
NONE											
SLIGHT											
MODERATE											
SEVERE											
EXTREME											

**Head**

	12	13	14	15	16	17	18
NONE							
SLIGHT							
MODERATE							
SEVERE							
EXTREME							